Distributions of Chromophoric Dissolved Organic Matter in New York Harbor

Alan F. Blumberg
Department of Civil, Environmental and Ocean Engineering
Stevens Institute of Technology
Castle Point on Hudson
Hoboken, New Jersey, 07030
phone: (201) 216-5289 fax: (201) 216-8372 email: ablumberg@stevens.edu

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LONG-TERM GOALS

The long-term goal of the project is to investigate the distributions of chromophoric dissolved organic matter (CDOM) in the New York/New Jersey Harbor and New York Bight system so as to facilitate a deeper understanding of the source and processes that control CDOM distributions in estuarine and coastal waters. CDOM source strengths and photochemical degradation processes were incorporated into a calibrated/validated three dimensional estuarine and coastal ocean forecast circulation model. The model results were compared with high resolution 4-dimensional measurements of physical water properties as well as CDOM data. The detailed distributions of modeled currents, temperatures, salinities, water levels and CDOM were used to help interpret the CDOM data.

OBJECTIVES

The objective was to develop a capability for incorporating CDOM source strengths and chemical processes into the currently operational New York Harbor Observation and Prediction System (NYHOPS, www.stevens.edu/maritimeforecast/). The first year objective was to build CDOM into NYHOPS and conduct simulations of CDOM distributions initially treating CDOM as a conservative tracer on the original NYHOPS model grid. In the second year we updated NYHOPS and its CDOM component to a higher-resolution model grid, updated CDOM sources and strengths in the model based on field observations, and included in the model CDOM photodegradation due to ultraviolet light based on a first-order decay rate measured through laboratory incubation experiments.

APPROACH

NYHOPS is a real-time, web-based estuarine and coastal ocean observing and modeling system for the waters of the New York Harbor region. The NYHOPS modeling system is based on the latest version of ECOMSED, the shallow water version of the Princeton Ocean Model (POM). The NYHOPS implementation of ECOMSED/POM is based on work led by the PI at the Stevens Institute of Technology (SIT) for the New York/New Jersey Harbor and New York Bight system. The spatial extent of the new high-resolution NYHOPS domain incorporates the core area of NY/NJ Harbor as defined by the Harbor Estuary Program and extends beyond to include the Hudson River Estuary, up to the Troy Dam, Delaware Bay, the NJ Atlantic sea shore and bays, all of Long Island Sound, Narragansett Bay, and the New York Bight out to the continental shelf (Figure 1). NYHOPS observations, managed and supported by SIT, consist of shore-based and moored platforms at strategic

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locations inside the harbor and at four sites along the coast of New Jersey, each with in-situ ocean and air-sea interaction measurements. In the second year of the project, the NYHOPS-supportive observation network has been expanded to include NOAA/NOS, USGS, NDBC, C-MAN, and UCONN stations (Figure 1).

In order to enhance the forecast product, the NYHOPS structure was redesigned to make better use of high-resolution inputs, including bathymetry, river forecasts, storm surge forecasts, and meteorological forecasts. To ensure accuracy of the modeling, the new high-resolution NYHOPS was validated against physical observational data from the expanded network of ocean and weather sensors, initially for a calendar year 2004 validation period, and then during the CDOM observing periods.

In order to a) decrease NYHOPS forecast-preparation time and b) allow for an easier, modular, design and further expansion of the CDOM model, the model code used for CDOM was a NYHOPS-coupled RCA code (Raw-Column-Aesop; http://www.hydroqual.com/pdf/RCA_Desc_doc.pdf). This modern water quality code is based on the USEPA WASP model, and has a long history of successful coupling with ECOMSED for water quality studies. CDOM was introduced in the RCA model based on guidance from a University of Massachusetts (UMASS), Boston team that collected CDOM observations in the Harbor. CDOM was simulated initially as a tracer by incorporating the field-estimated CDOM source strengths into NYHOPS. In the second year, along with the updates to the high-resolution model, photodegradation of CDOM due to ultraviolet radiation at the water surface was included in the model code as a 0.168/day first order decay rate applied at the surface layer during daylight hours.

WORK COMPLETED

The work completed includes:

1) Ensuring the continuous flow of NYHOPS-supporting real-time or near-real-time (collected 0-5hrs in the past) data from multiple agencies: a) 13 SIT-maintained sites, including 2 HR-radar systems located within the NY harbor, b) 2 Rutgers-maintained HF-Radar systems, c) 2 C-MAN stations, d) 1 NOS ADCP, e) 5 NDBC stations, f) 33 NOS stations, g) 4 UCONN-maintained stations, h) 40 USGS stations, i) 6 NY Met stations providing overland observations of local meteorological conditions, j)Vessel-based conductivity and temperature sensors.

2) Comparisons of these observations with the NYHOPS forecast results at many of these sites, updated and displayed hourly – along with statistical measures of model performance – on the NYHOPS website.

3) Incorporation of river inflows into the high-resolution forecast system data stream using real time data and Advanced Hydrologic Prediction Service forecasts.

4) Development of an off-line capability to simulate passive constituents using RCA and transport fields from the NYHOPS high-resolution forecast output stream.

5) Configured system to accept source strength inputs of CDOM and conducted simulations to ensure that the system is working properly with CDOM as a conservative tracer.

6) Furthermore, CDOM component strengths are also independently simulated in parallel to facilitate component analysis.

7) Incorporated preliminary estimates of CDOM source strengths to six end members based on the UMASS-Boston team's recommendations.

8) Configured system to accept photodegradation kinetics for CDOM based on incubation experiments.

9) Incorporated the CDOM model into the NYHOPS forecast website for use by the data-collecting UMASS-Boston team

10) Adjusted the preliminary source strengths as suggested by field observations.

RESULTS

An RCA-based NYHOPS CDOM module was developed to execute in conjunction with daily NYHOPS hydro/waves forecast runs so that transport output from ECOMSED/POM is directly linked to the module. The two models share the same numerical grid structure and underlying numerical solution techniques. To ensure that the two models communicate correctly a "10s" test was conducted. The NYHOPS submodel was initialized with 10 (tracer units) everywhere; all inflows were assigned that same concentration. The model was run for a 30 period using January 2004 river inflows. Model concentrations never deviated from the expected 10 units.

The original NYHOPS forecast system included 25 simplified river systems based on 27 real time USGS gages. Based on newly available USGS real time stations, and work completed recently (Georgas, 2006), the high-resolution NYHOPS system includes 93 river systems, with river outlets spanning seven coastal states (NY, NJ, CT, RI, DE, PA, MA), based on 74 real time USGS gages. Figure 2 shows the contributing simulated river watersheds. For example, the direct tributary outlets to the Hudson River system north of the Battery, NY, including the river itself north of Troy, NY, have now been increased to 20 from the original 14. Similarly, the direct tributary outlets to Raritan Bay, NJ, have increased to 11 from the original 4. Rivers and outlets in the states of RI, DE, PA, and MA are all new additions as well. The detailed representation of river systems increased the ability of identifying and tracking CDOM sources in the area of interest.

Similar to the higher resolution characterization of individual watershed non-point sources described above, the original network of water treatment plants and other water discharging industrial facilities was expanded to include 280 dischargers, 39 of which are thermal dischargers, the remaining being freshwater-discharging treatment plants, characterized as major dischargers by USEPA (Figure 3). Mean discharge from all plants is estimated to equal approximately 1,000 m3/s, which is of the same order to the estimated long-term-average flow of the Connecticut (~560m3/s) and Delaware (~400m3/s) rivers combined. 80% of that flow is due to re-circulating flow within thermal plants, the remaining 20% (~200m3/s) being freshwater flow added to the system mainly by public sewage treatment plants. The latter value is approximately equal to 1/3 of the mean freshwater flow reaching the southern tip of Manhattan due to the Hudson River and all its tributaries. Obviously, the detailed inclusion of these freshwater systems is of primary importance to any high-resolution forecasting system of the NY/NJ Harbor Estuary and its coastal ocean, both in terms of salinity and temperature prediction, but also in terms of currents and pollutant dispersion predictions due to the strong estuarine

(density-driven) circulation. Moreover, these 280 independent sources may be CDOM sources as well, and their inclusion allows for simulation of their effect on CDOM distributions.

The key tributaries for this study are the Hackensack, Passaic, Hudson, and Raritan rivers (Figure 4). CDOM end members were provided for these tributaries by R. F. Chen, G. B. Gardner and Y. Tian of UMASS, Boston who are working on a very closely linked ONR effort. Two point source end members were also investigated: The Bergen County water treatment plant discharging in the Hackensack River and the Port Richmond water treatment plant discharging in the Kill van Kull that, along with Arthur Kill to its south west, connects Raritan and Newark Bays (Figure 4).

An example of data-driven hypotheses that can be tested through the use of the model is the inclusion of the Bergen County facility as a CDOM source for the Hackensack River. This was hypothesized based on data collected by the Boston team during October 2006. Figures 5 through 7 explain the impact of that treatment plant to local CDOM concentrations along the Hackensack River. Of particular significance is the fact that the Hackensack river watershed itself contributes, on the average, a smaller freshwater input than the mean freshwater input coming from the treatment plant: The median flow of the Hackensack river is around 1.8m3/s, while the median flow of the treatment plant is around 3.6m3/s, roughly double.

Figures 8 and 9 show the flows of the Passaic and Hackensack Rivers, respectively, at the point they enter the model grid, based on the available USGS gage data for calendar year 2004. Note that the Passaic River has approximately an order of magnitude greater flow than the Hackensack. In fact, the model shows that CDOM from the larger Passaic River has an impact on the Hackensack River proper too. This notion has been introduced in the component analysis of Figure 7, where the Hackensack River and Bergen County plant CDOM loads sit on top of a Passaic-river-related background CDOM concentration. It is also seen in Figures 10 and 11 which show tracer concentrations following a continuous, uniform tracer release from all rivers in the NYHOPS model. During ebb tide in the early morning of January 2nd, 2004 (Figure 4), the Passaic River plume is visibly entering Newark Bay, while tracer in the smaller Hackensack, is barely measured for most of the visible span of that Newark Bay tributary. Six hours later (Figure 5), the flooding tide brings a considerable load from the Passaic River plume into the Hackensack River through its Newark Bay outlet, while the Hackensack plume itself moves to the North. This was an early confirmation of the hypothesis that constituents originating in the Passaic River can easily travel up the Hackensack River.

Compared to the significance of the Bergen County facility as a potential source of CDOM, the alleged significance of a second water treatment plant investigated by the NYHOPS CDOM model appears to be considerably smaller. The NYC-DEP Port Richmond Plant outfall in the Kill Van Kull (Figure 3) is predicted to have an almost negligible effect on the local distribution of CDOM, in spite of its higher concentration (200 QSU). This is hypothesized to be due to a smaller mean flow (1.5m3/s), and, more importantly, rigorous mixing and dispersion in the area of the outfall (Figure 12).

IMPACT/APPLICATIONS

The work presented here contributes significantly to the understanding of the mechanisms by which CDOM enters and disperses/accumulates in the nearshore marine environment. It provides a major step forward to the incorporation of CDOM into an advanced, integrated system of oceanographic and meteorological sensors and operational littoral-ocean forecasting models. The model results of CDOM distributions provide a means of estimating and predicting the ecological dynamics of the coastal zone.

The operational model has shown that it can evaluate observation-based hypotheses of source strengths, and can continue to do so, testing, for example, an alleged CDOM load from the Meadowlands salt marshes (Figure 6). It can also test the significance of photodegradation to CDOM distributions. Hindcasting of observation periods can help fine-tune such scientific findings. By assimilating satellite remote sensing ocean color data from programs like CZCS, TOCS, SeaWiFS, and IKONOS, important ecological events may be forecasted. A recent study shoes that chlorophyll concentrations, combined absorption of detrital and dissolved material (CDOM) at 443nm, and backscattering coefficient at 443 nm (a measure of the total suspended matter) can be retrieved from SeaWiFS data (Li et al., submitted).

The observational network and modeling system are parts of the integrated, sustained ocean observing system envisioned by the National Oceanographic Partnership Program (NOPP), under the OCEAN.US office, and the Integrated Ocean Observing System (IOOS). The PI has been an active participant in the Mid-Atlantic Coastal Ocean Observing Regional Association (MACOORA).

RELATED PROJECTS

This effort is a companion study to the ONR funded study of R. F. Chen, G. Bb Gardner and Y. Tian of the University of Massachusetts, Boston. Their study, “Predicting Chromophoric Dissolved Organic Matter Distributions in Coastal Waters” will provide the data upon which the analysis of this proposed is based.

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Wei, L., Stamnes, K., Spurr, R., and Stamnes J. *Simultaneous Retrieval of Aerosol and Ocean Properties by Optimal Estimation: SeaWiFS Case Studies for the Santa Barbara Channel.* International Journal of Remote Sensing. Submitted.

PUBLICATIONS/PRESENTATIONS

N. Georgas, 2006. *Using real time USGS river gages to simulate fluvial contributions to the high-resolution New York Harbor Observation and Prediction system*. Stevens Institute of Technology.

G. B. Gardner, R. F. Chen, A. F. Blumberg, N. Georgas, W. Huang, and F. Peri. *Measurement and Modeling of Chromophoric Dissolved Organic Matter in an Urban Estuary.* Presented at the American Society of Limnology and Oceanography (ASLO) 2007 Aquatic Sciences Meeting. February 4-9, 2007. Santa Fe, New Mexico.

HONORS/AWARDS/PRIZES

Alan F. Blumberg, Stevens Institute of Technology, Elected Fellow, American Society of Civil Engineering.

Alan F. Blumberg, Stevens Institute of Technology, Appointed to the Science Advisory Board (SAB), U.S. Environmental Protection Agency.

Nickitas Georgas, Stevens Institute of Technology, 2006 American Shore and Beach Preservation Association Educational Award.

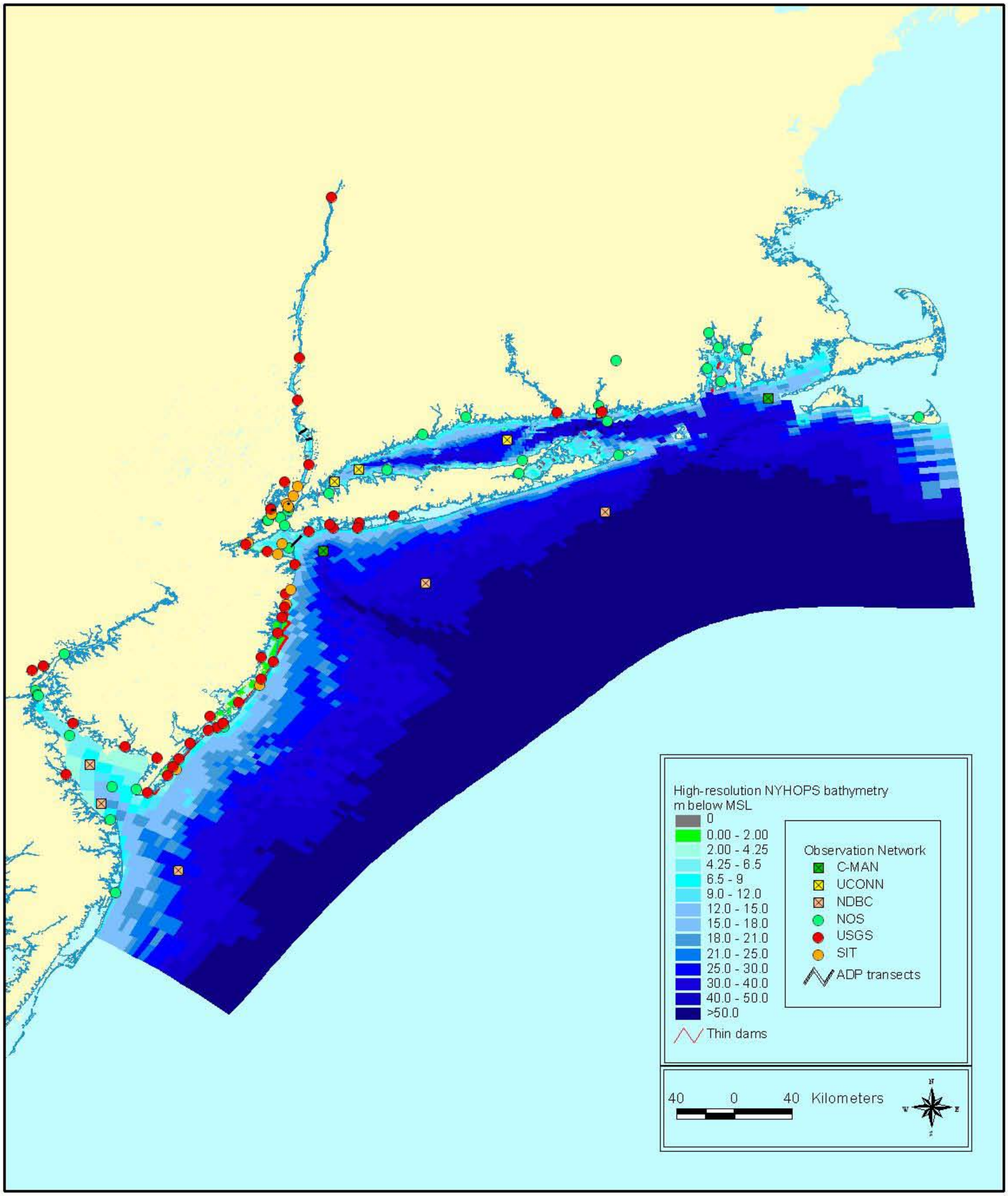


Figure 1. NYHOPS-supportive observation network. Year 2007 expansion to include data collected by agencies other than Stevens Institute of Technology. Station locations are superimposed on the updated (since Jan 17th 2007) high-resolution NYHOPS model that includes CDOM sources and kinetics.

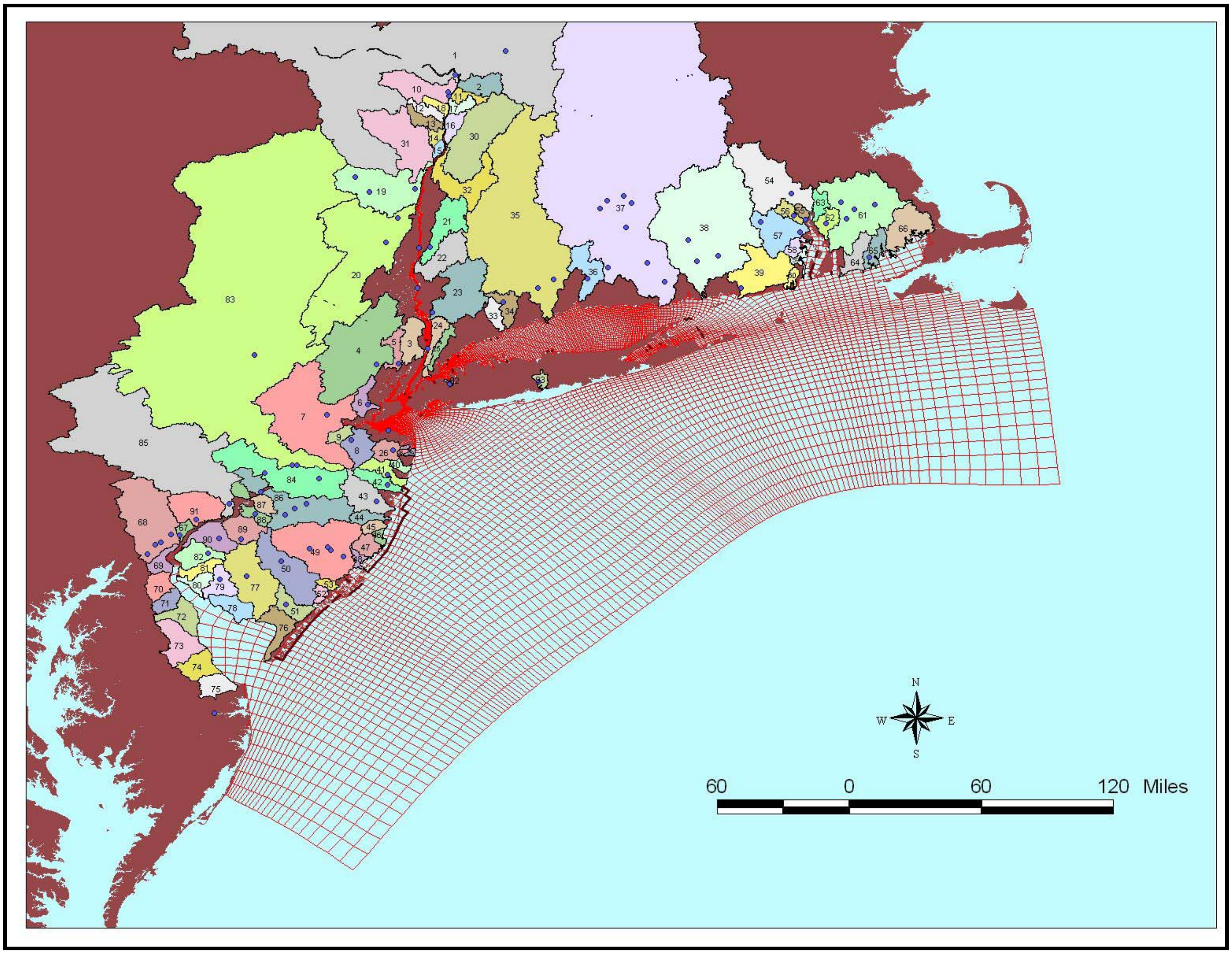
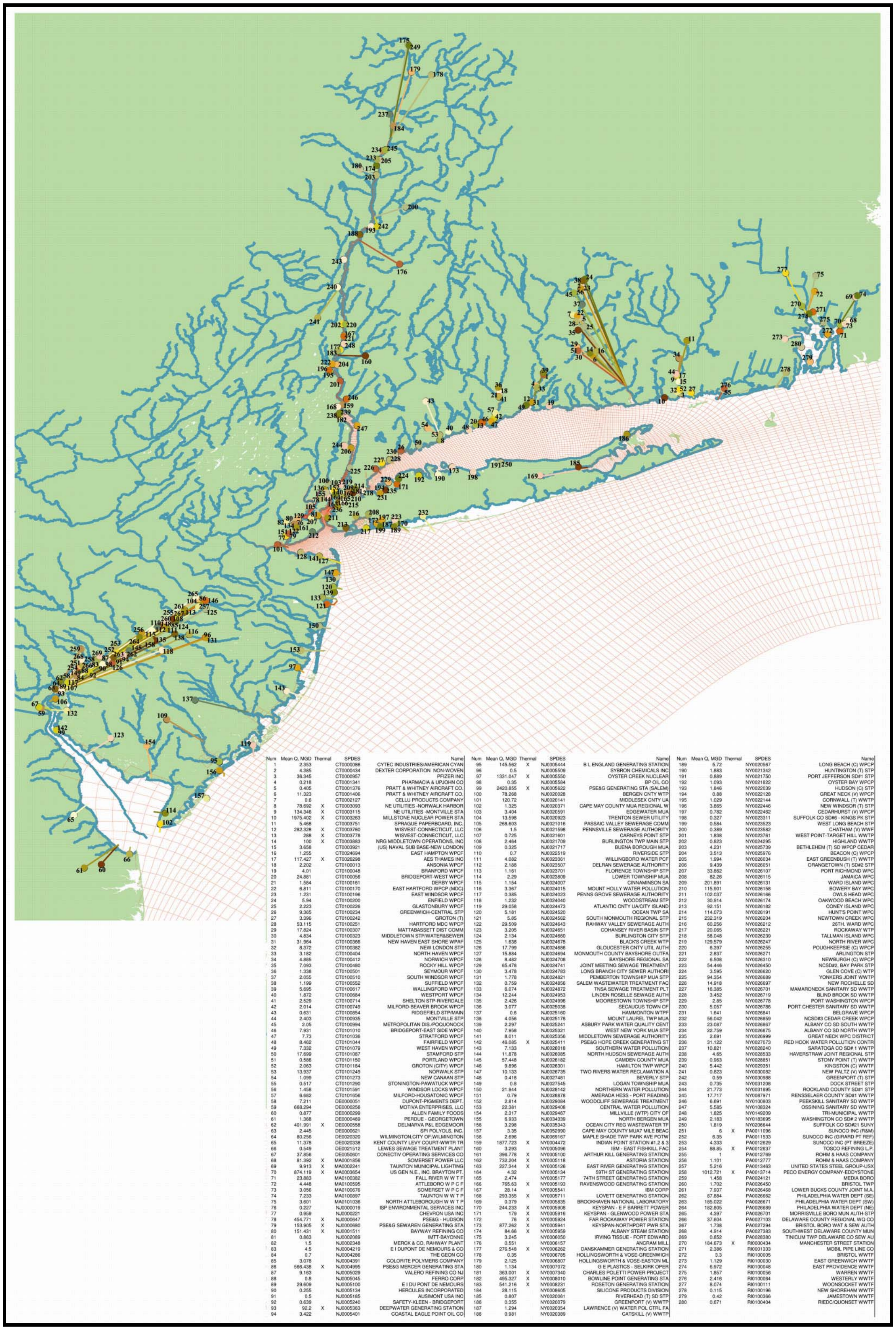


Figure 2. Individual rivers and streams in NYHOPS (colored watershed polygons), with locations of applicable real time gages (blue dots). The variable, curvilinear, high-resolution NYHOPS grid cells are also delineated with red.



Num	Mean Q, MGD	Thermal	SPDES	Name
1	2.353		CT0000086	CYTEC INDUSTRIES/AMERICAN CYAN
2	4.385		CT0000434	DEXTER CORPORATION NON-WOVEN
3	36.345		CT0000957	PFIZER INC
4	0.218		CT0001341	PHARMACIA & UPJOHN CO
5	0.405		CT0001376	PRATT & WHITNEY AIRCRAFT CO.
6	11.323		CT0001406	PRATT & WHITNEY AIRCRAFT CO.
7	0.6		CT0002127	CELLU PRODUCTS COMPANY
8	78.692	X	CT0003093	NE UTILITIES -NORWALK HARBOR
9	134.346	X	CT0003115	NE UTILITIES -MONTVILLE STA
10	1975.402	X	CT0003263	MILLSTONE NUCLEAR POWER STA
11	5.468		CT0003751	SPRAGUE PAPERBOARD, INC.
12	282.328	X	CT0003760	WISVEST-CONNECTICUT, LLC
13	288	X	CT0003778	WISVEST-CONNECTICUT, LLC
14	100	X	CT0003883	NRG MIDDLETOWN OPERATIONS, INC
15	3.658		CT0003921	(US) NAVAL SUB BASE-NEW LONDON
16	1.255		CT0024694	EAST HAMPTON WPCF
17	117.427	X	CT0026298	AES THAMES INC
18	2.202		CT0100013	ANSONIA WPCF
19	4.01		CT0100048	BRANFORD WPCF
20	24.881		CT0100056	BRIDGEPORT-WEST WPCF
21	1.584		CT0100161	DERBY WPCF
22	6.811		CT0100170	EAST HARTFORD WPCP (MDC)
23	1.231		CT0100196	EAST WINDSOR WPCF
24	5.94		CT0100200	ENFIELD WPCF
25	2.223		CT0100226	GLASTONBURY WPCF
26	9.365		CT0100234	GREENWICH-CENTRAL STP
27	3.396		CT0100242	GROTON (T)
28	53.115		CT0100251	HARTFORD MDC WPCP
29	17.824		CT0100307	MATTABASSETT DIST COMM
30	4.834		CT0100323	MIDDLETOWN STP/WATER&SEWER
31	31.964		CT0100366	NEW HAVEN EAST SHORE WPAF
32	8.372		CT0100382	NEW LONDON STP
33	3.182		CT0100404	NORTH HAVEN WPCF
34	4.885		CT0100412	NORWICH WPCF
35	7.093		CT0100480	ROCKY HILL WPCP
36	1.338		CT0100501	SEYMOUR WPCF
37	2.055		CT0100510	SOUTH WINDSOR WPCF
38	1.199		CT0100552	SUFFIELD WPCF
39	5.695		CT0100617	WALLINGFORD WPCF
40	1.872		CT0100684	WESTPORT WPCF
41	2.529		CT0100714	SHELTON STP-RIVERDALE
42	2.014		CT0100749	MILFORD-BEAVER BROOK WPCP
43	0.631		CT0100854	RIDGEFIELD STP/MAIN
44	2.403		CT0100935	MONTVILLE STP
45	2.05		CT0100994	METROPOLITAN DIS./POQUONOCK
46	7.931		CT0101010	BRIDGEPORT-EAST SIDE WPCF
47	7.73		CT0101036	STRATFORD WPCF
48	8.462		CT0101044	FAIRFIELD WPCF
49	7.332		CT0101079	WEST HAVEN WPCF
50	17.699		CT0101087	STAMFORD STP
51	0.586		CT0101150	PORTLAND WPCF
52	2.063		CT0101184	GROTON (CITY) WPCF
53	13.937		CT0101249	NORWALK STP
54	1.099		CT0101273	NEW CANAAN STP
55	0.517		CT0101290	STONINGTON-PAWATUCK WPCF
56	1.458		CT0101591	WINDSOR LOCKS WPCF
57	6.682		CT0101656	MILFORD-HOUSATONIC WPCF
58	7.211		DE0000051	DUPONT-PIGMENTS DEPT.
59	668.294		DE0000256	MOTIVA ENTERPRISES, LLC
60	0.877		DE0000299	ALLEN FAMILY FOODS
61	1.368		DE0000469	PERDUE - GEORGETOWN
62	401.991	X	DE0000558	DELMARVA P&L EDGEMOOR
63	2.445		DE0000621	SPI POLYOLS, INC.
64	80.256		DE0020320	WILMINGTON,CITY OF;WILMINGTON
65	11.378		DE0020338	KENT COUNTY LEVY COURT-WWTR TR
66	0.549		DE0021512	LEWES SEWAGE TREATMENT PLANT
67	37.856		DE0050601	CONECTIV OPERATING SERVICES CO
68	81.392	X	MA0001856	SOMERSET POWER LLC
69	9.913	X	MA0002241	TAUNTON MUNICIPAL LIGHTING
70	874.119	X	MA0003654	US GEN N.E., INC. BRAYTON PT.
71	23.883		MA0100382	FALL RIVER W W T F
72	4.448		MA0100595	ATTLEBORO W P C F
73	3.056		MA0100676	SOMERSET W P C F
74	7.233		MA0100897	TAUNTON W W T P
75	3.601		MA0101036	NORTH ATTLEBOROUGH W W T P
76	0.227		NJ0000019	ISP ENVIRONMENTAL SERVICES INC
77	0.959		NJ0000221	CHEVRON USA INC
78	454.771	X	NJ0000647	PSE&G - HUDSON
79	153.905	X	NJ0000680	PSE&G SEWAREN GENERATING STA
80	151.431	X	NJ0001511	BAYWAY REFINING CO
81	0.863		NJ0002089	IMTT-BAYONNE
82	1.5		NJ0002348	MERCK & CO, RAHWAY PLANT
83	4.5		NJ0004219	E I DUPONT DE NEMOURS & CO
84	0.7		NJ0004286	THE GEON CO
85	3.078		NJ0004391	COLORITE POLYMERS COMPANY
86	566.438	X	NJ0004995	PSE&G MERCER GENERATING STA
87	9.163		NJ0005029	VALERO REFINING CO NJ
88	0.8		NJ0005045	FERRO CORP
89	29.609		NJ0005100	E I DU PONT DE NEMOURS
90	0.255		NJ0005134	HERCULES INCORPORATED
91	0.5		NJ0005185	AUSIMONT USA INC
92	0.639		NJ0005240	SAFETY-KLEEN - BRIDGEPORT
93	92.2	X	NJ0005363	DEEPWATER GENERATING STATION
94	3.422		NJ0005401	COASTAL EAGLE POINT OIL CO
95	145.562	X	NJ0005444	B L ENGLAND GENERATING STATION
96	0.5		NJ0005509	SYBRON CHEMICALS INC
97	1331.047	X	NJ0005550	OYSTER CREEK NUCLEAR
98	0.35		NJ0005584	BP OIL CO
99	2420.855	X	NJ0005622	PSE&G GENERATING STA (SALEM)
100	78.268		NJ0020028	BERGEN CNTY WTP
101	120.72		NJ0020141	MIDDLESEX CNTY UA
102	1.325		NJ0020371	CAPE MAY COUNTY MUA REGIONAL W
103	3.404		NJ0020591	EDGEWATER MUA
104	13.598		NJ0020923	TRENTON SEWER UTILITY
105	268.603		NJ0021016	PASSAIC VALLEY SEWERAGE COMM
106	1.5		NJ0021598	PENNSVILLE SEWERAGE AUTHORITY
107	0.725		NJ0021601	CARNEYS POINT STP
108	2.464		NJ0021709	BURLINGTON TWP MAIN STP
109	0.325		NJ0021717	BUENA BOROUGH MUA
110	0.7		NJ0022519	RIVERSIDE STP
111	4.082		NJ0023361	WILLINGBORO WATER PCF
112	2.188		NJ0023507	DELRAN SEWERAGE AUTHORITY
113	1.161		NJ0023701	FLORENCE TOWNSHIP STP
114	2.29		NJ0023809	LOWER TOWNSHIP MUA
115	1.154		NJ0024007	CINNAMINSON SA
116	3.367		NJ0024015	MOUNT HOLLY WATER POLLUTION
117	0.385		NJ0024023	PENNS GROVE SEWERAGE AUTHORITY
118	1.232		NJ0024040	WOODSTREAM STP
119	29.058		NJ0024473	ATLANTIC CNTY UA/CITY ISLAND
120	5.181		NJ0024520	OCEAN TWP SA
121	5.85		NJ0024562	SOUTH MONMOUTH REGIONAL STP
122	29.509		NJ0024643	RAHWAY VALLEY SEWERAGE AUTH
123	3.205		NJ0024651	COHANSEY RIVER BASIN STP
124	2.134		NJ0024660	BURLINGTON CITY STP
125	1.638		NJ0024678	BLACK'S CREEK WTP
126	17.799		NJ0024686	GLOUCESTER CNTY UTIL AUTH
127	15.884		NJ0024694	MONMOUTH COUNTY BAYSHORE OUTFA
128	8.482		NJ0024708	BAYSHORE REGIONAL SA
129	65.478		NJ0024741	JOINT MEETING SEWAGE TREATMENT
130	3.478		NJ0024783	LONG BRANCH CITY SEWER AUTHORI
131	1.778		NJ0024821	PEMBERTON TOWNSHIP MUA STP
132	0.759		NJ0024856	SALEM WASTEWATER TREATMENT FAC
133	6.074		NJ0024872	TNSA SEWAGE TREATMENT PLT
134	12.244		NJ0024953	LINDEN ROSELLE SEWAGE AUTH
135	2.426		NJ0024996	MOORESTOWN TOWNSHIP STP
136	3.077		NJ0025038	SECAUCUS TOWN OF
137	0.6		NJ0025160	HAMMONTON WTPF
138	4.056		NJ0025178	MOUNT LAUREL TWP MUA
139	2.297		NJ0025241	ASBURY PARK WATER QUALITY CENT
140	7.958		NJ0025321	WEST NEW YORK MUA STP
141	8.011		NJ0025356	MIDDLETOWN SEWERAGE AUTHORITY
142	46.085	X	NJ0025411	PSE&G HOPE CREEK GENERATING ST
143	7.133		NJ0026018	SOUTHERN WATER POLLUTION
144	11.878		NJ0026085	NORTH HUDSON SEWERAGE AUTH
145	57.448		NJ0026182	CAMDEN COUNTY MUA
146	9.896		NJ0026301	HAMILTON TWP WPCF
147	10.133		NJ0026735	TWO RIVERS WATER RECLAMATION A
148	0.418		NJ0027481	BEVERLY STP
149	0.8		NJ0027545	LOGAN TOWNSHIP MUA
150	21.944		NJ0028142	NORTHERN WATER POLLUTION
151	0.79		NJ0028878	AMERADA HESS - PORT READING
152	2.814		NJ0029084	WOODCLIFF SEWERAGE TREATMENT
153	22.381		NJ0029408	CENTRAL WATER POLLUTION
154	2.317		NJ0029467	MILLVILLE (WTP) CITY OF
155	6.933		NJ0034339	NORTH BERGEN MUA
156	3.298		NJ0035343	OCEAN CITY REG WASTEWATER TF
157	3.35		NJ0052990	CAPE MAY COUNTY MUA7 MILE BEAC
158	2.696		NJ0069167	MAPLE SHADE TWP PARK AVE POTW
159	1877.723	X	NY0004472	INDIAN POINT STATION #1,2 & 3
160	3.293		NY0005096	IBM - EAST FISHKILL FAC
161	396.778	X	NY0005100	ARTHUR KILL GENERATING STATION
162	732.204	X	NY0005118	ASTORIA STATION
163	227.344	X	NY0005126	EAST RIVER GENERATING STATION
164	4.32		NY0005134	59TH ST GENERATING STATION
165	2.474		NY0005177	74TH STREET GENERATING STATION
166	765.63	X	NY0005193	RAVENSWOOD GENERATING STATION
167	28.14		NY0005541	IBM CORP
168	293.355	X	NY0005711	LOVETT GENERATING STATION
169	0.379		NY0005835	BROOKHAVEN NATIONAL LABORATORY
170	244.233	X	NY0005908	KEYSPAN - E F BARRETT POWER
171	179	X	NY0005916	KEYSPAN - GLENWOOD POWER STA
172	76	X	NY0005924	FAR ROCKAWAY POWER STATION
173	877.262	X	NY0005941	KEYSPAN-NORTHPORT PWR STA
174	84.66	X	NY0005959	ALBANY STEAM STATION
175	3.245		NY0006050	IRVING TISSUE - FORT EDWARD
176	0.551		NY0006157	ANCRAM MILL
177	276.548	X	NY0006262	DANSKAMMER GENERATING STATION
178	0.35		NY0006785	HOLLINGSWORTH & VOSE-GREENWICH
179	2.125		NY0006807	HOLLINGSWORTH & VOSE-EASTON ML
180	1.134		NY0007072	G E PLASTICS - SELKIRK OPER
181	363.001	X	NY0007340	CHARLES POLETTI POWER PROJECT
182	495.327	X	NY0008010	BOWLINE POINT GENERATING STA
183	541.216	X	NY0008231	ROSETON GENERATING STATION
184	28.115		NY0008605	SILICONE PRODUCTS DIVISION
185	0.807		NY0020061	RIVERHEAD (T) SD STP
186	0.355		NY0020079	GREENPORT (V) WWTP
187	1.294		NY0020354	LAWRENCE (V) WATER POL CTRL FA
188	0.981		NY0020389	CATSKILL (V) WWTP
189	5.72		NY0020567	LONG BEACH (C) WPCP
190	1.883		NY0021342	HUNTINGTON (T) STP
191	0.889		NY0021750	PORT JEFFERSON SD#1 STP
192	1.093		NY0021822	OYSTER BAY WPCP
193	1.846		NY0022039	HUDSON (C) STP
194	0.88		NY0022128	GREAT NECK (V) WPCP
195	1.029		NY0022144	CORNWALL (T) WWTP
196	3.865		NY0022446	NEW WINDSOR (T) STP
197	0.792		NY0022462	CEDARHURST (V) WPCP
198	0.327		NY0023311	SUFFOLK CO SD#6 - KINGS PK STP
199	0.584		NY0023523	WEST LONG BEACH STP
200	0.389		NY0023582	CHATHAM (V) WWTP
201	1.838		NY0023761	WEST POINT-TARGET HILL WWTP
202	0.623		NY0024295	HIGHLAND WWTP
203	4.231		NY0025739	BETHLEHEM (T) SD WPCP CEDAR
204	3.513		NY0025976	BEACON (C) WPCP
205	1.994		NY0026034	EAST GREENBUSH (T) WWTP
206	9.439		NY0026051	ORANGETOWN (T) SD#2 STP
207	33.862		NY0026107	PORT RICHMOND WPCP
208	82.26		NY0026115	JAMAICA WPCP
209	201.891		NY0026131	WARD ISLAND WPCP
210	115.901		NY0026158	BOWERY BAY WPCP
211	102.037		NY0026166	OWLS HEAD WPCP
212	30.914		NY0026174	OAKWOOD BEACH WPCP
213	92.151		NY0026182	CONEY ISLAND WPCP
214	114.073		NY0026191	HUNTS POINT WPCP
215	232.319		NY0026204	NEWTOWN CREEK WPCP
216	60.256		NY0026212	26TH. WARD WPCP
217	20.065		NY0026221	ROCKAWAY WTP
218	58.048		NY0026239	TALLMAN ISLAND WPCP
219	129.579		NY0026247	NORTH RIVER WPCP
220	6.397		NY0026255	POUGHKEEPSIE (C) WPCP
221	2.837		NY0026271	ARLINGTON STP
222	6.508		NY0026310	NEWBURGH (C) WPCP
223	54.446		NY0026450	NCSD#2, BAY PARK STP
224	3.595		NY0026620	GLEN COVE (C) WTP
225	94.354		NY0026689	YONKERS JOINT WWTP
226	14.918		NY0026697	NEW ROCHELLE SD
227	16.385		NY0026701	MAMARONECK SANITARY SD WWTP
228	3.452		NY0026719	BLIND BROOK SD WWTP
229	2.85		NY0026778	PORT WASHINGTON WPCP
230	5.057		NY0026786	PORT CHESTER SANITARY SD WWTP
231	1.641		NY0026841	BELGRAVE WPCP
232	56.042		NY0026859	NCSD#3 CEDAR CREEK WPCP
233	23.087		NY0026867	ALBANY CO SD SOUTH WWTP
234	22.759		NY0026875	ALBANY CO SD NORTH WWTP
235	2.691		NY0026999	GREAT NECK WPC DISTRICT
236	31.132		NY0027073	RED HOOK WATER POLLUTION CONTR
237	10.821		NY0028240	SARATOGA CO SD# 1 WWTP
238	4.65		NY0028533	HAVERSTRAW JOINT REGIONAL STP
239	0.963		NY0028851	STONY POINT (T) WWTP
240	5.442		NY0029351	KINGSTON (C) WWTF
241	0.823		NY0030082	NEW PALTZ (V) WWTF
242	0.59		NY0030988	GREENPORT (T) STP
243	0.735		NY0031208	DOCK STREET STP
244	21.773		NY0031895	ROCKLAND COUNTY SD#1 STP
245	17.717		NY0087971	RENSSELAER COUNTY SD#1 WWTP
246	6.691		NY0100803	PEEKSKILL SANITARY SD WWTP
247	5.585		NY0108324	OSSINING SANITARY SD WWTP
248	1.825		NY0149209	TRI-MUNICIPAL WWTP
249	2.183		NY0183695	WASHINGTON CO SD# 2 WWTP
250	1.819		NY0206644	SUFFOLK CO SD#21 SUNY
251	6	X	PA0011096	SUNOCO INC (R&M)
252	6.35		PA0011533	SUNOCO INC (GIRARD PT REF)
253	4.333		PA0012629	SUNOCO INC (PT BREEZE)
254	88.85	X	PA0012637	TOSCO REFINING L.P.
255	1		PA0012769	ROHM & HAAS COMPANY
256	1.101		PA0012777	ROHM & HAAS COMPANY
257	5.216		PA0013463	UNITED STATES STEEL GROUP-USX
258	1012.721	X	PA0013714	PECO ENERGY COMPANY-EDDYSTONE
259	1.458		PA0024121	MEDIA BORO
260	1.702		PA0026450	BRISTOL TWP
261	7.937		PA0026468	LOWER BUCKS COUNTY JOINT M.A.
262	87.884		PA0026662	PHILADELPHIA WATER DEPT (SE)
263	185.022		PA0026671	PHILADELPHIA WATER DEPT (SW)
264	182.805		PA0026689	PHILADELPHIA WATER DEPT (NE)
265	4.397		PA0026701	MORRISVILLE BORO MUN AUTH STP
266	37.604		PA0027103	DELAWARE COUNTY REGIONAL WQ CO
267	1.738		PA0027294	BRISTOL BORO WAT & SEW AUTH
268	4.914		PA0027383	SOUTHWEST DELAWARE COUNTY MUN
269	0.852		PA0028380	TINICUM TWP DELAWARE CO SEW AU
270	184.673	X	RI0000434	MANCHESTER STREET STATION
271	2.386		RI0001333	MOBIL PIPE LINE CO
272	3.3		RI0100005	BRISTOL WWTF
273	1.129		RI0100030	EAST GREENWICH WWTF
274	6.972		RI0100048	EAST PROVIDENCE WWTF
275	1.857		RI0100056	WARREN WWTF
276	2.416		RI0100064	WESTERLY WWTF
277	8.074		RI0100111	WOONSOCKET WWTF
278	0.115		RI0100196	NEW SHOREHAM WWTF
279	0.42		RI0100366	JAMESTOWN WWTF
280	0.671		RI0100404	RIEDC/QUONSET WWTF

Figure 3. The new high-resolution HIGHRES model includes the ability to simulate 280 independent point sources of CDOM shown as dots in this figure. Lines connect location of actual and simulated outfalls, due to limitations on the extent of the model grid. The embedded table lists all 280 sources by name and mean discharge.

Figure 4. Non-point source (reverie, in red) and point-source (treatment plant, in green) CDOM end-point strengths, in quantinine salinity units (QSU), as simulated in the Stevens IT NYHOPS model, based on observation-derived guidance by the Umass Boston team.

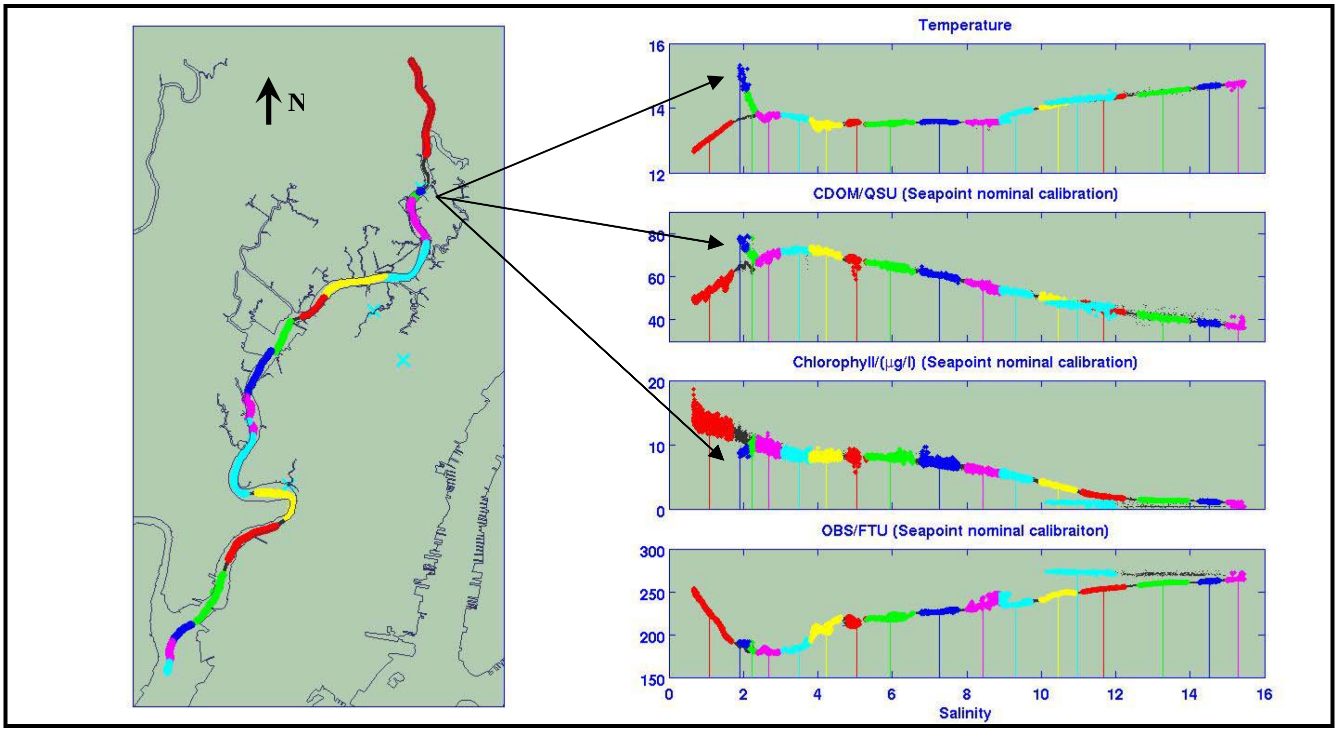


Figure 5. Results of the October 2006 CDOM survey of the Hackensack River (map on the left). The panels to the right show different parameters against salinity, the latter typically increasing from north to south, as Hackensack River freshwater dilutes Newark Bay salt water. Colors of data shown correspond to colors on the transect map. Panels from top to bottom: a) Temperature (ºC) vs. Salinity (psu) (T/S-diagram), b) CDOM (QSU) vs. Salinity (psu), c) Chlorophyll (ug/L) vs. Salinity (psu), and d) Optical Back Scatter (FTU) vs. Salinity. The survey was conducted by a UMASS Boston team, guided by the NYHOPS CDOM forecast model. The time of the survey coincided with the end of the ebb tide, and reached the northern end of the transect around low water. The team towed an ECO Mini-shuttle, side-scan sonar, and ADCP along the Hackensack River, and took surface-leaving radiance measurements underway from a 25 ft research vessel. Note the apparent effect of the Bergen County water treatment plant on CDOM concentrations (black arrows). A local maximum in CDOM and water temperature and a local minimum in chlorophyll are observed around the outfall location. Treatment plant effluent is usually at a higher than ambient temperature due to the biological processes involved in the treatment of sewage, hence the local rise in temperature observed. The local rise in CDOM cannot be explained by a local phytoplankton bloom, as chlorophyll concentrations were actually lower around the outfall.

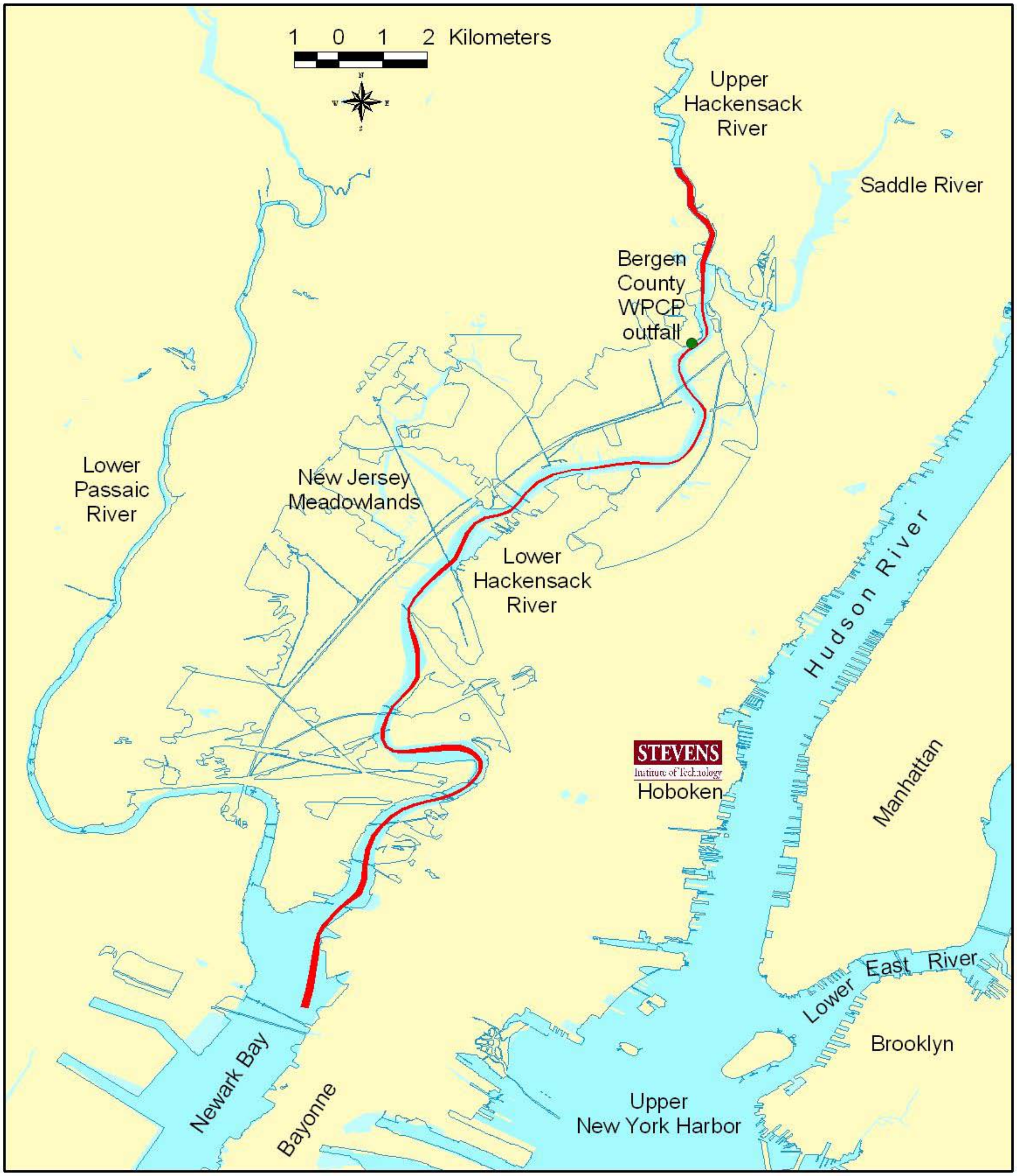


Figure 6. Hackensack River and vicinity. Figure shows the Hackensack river, and, in red, the model transect used to compare simulation results (shown on Figure 7) with Mini-shuttle observations collected by the UMASS, Boston research team. The outfall of the Bergen County Water Pollution Control Plant is also shown (as a green dot). The Plant was estimated to be a source of CDOM in the river.

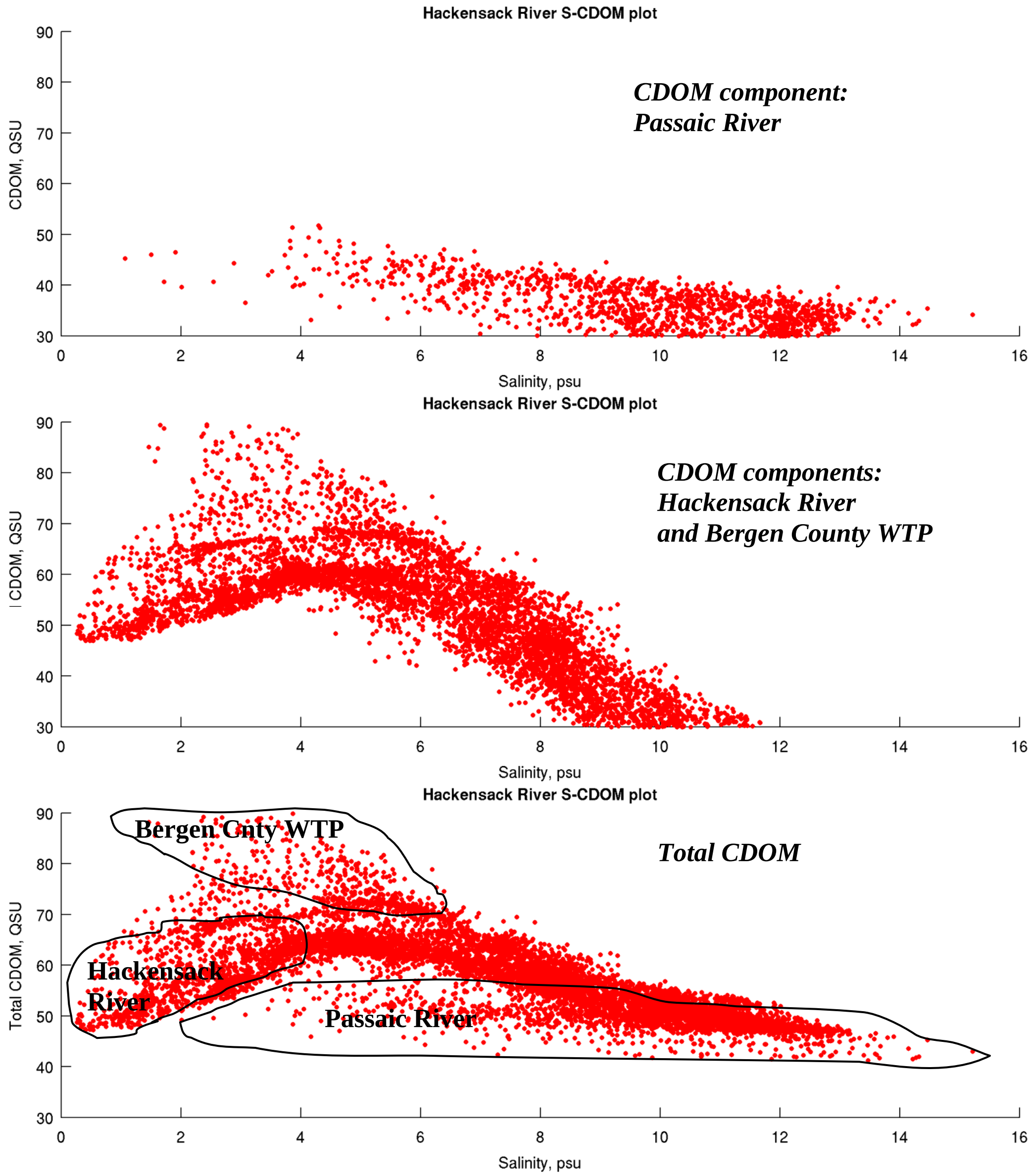


Figure 7. Component analysis of the high-resolution NYHOPS CDOM simulations for 24-26 March 2007, after the RCA CDOM module was configured to include the apparent sources based on the results of the October 2006 Hackensack river survey. Model results are taken from the model cells of the Hackensack river transect shown in Figure 6, which largely coincides with the transect the October 2006 observations were collected along shown in Figure 5 (left panel). The X-and-Y-axes scales of the panels have been set to equal the scales of the S-CDOM observations plot (2nd plot from the top right in Figure 5). Top panel: Source is the Passaic River alone, with a nominal end-member concentration of 80 QSU. Center panel: Sources are the Hackensack River, at 41 SQU, and the Bergen County water treatment facility at 111 QSU. Bottom panel: Total CDOM along the Hackensack transect based on all investigated sources shown on Figure 4. The last panel shows a good correspondence of the model with the observed data. The significant scatter of the data is due to tidal and meteorological influences within the three day period.

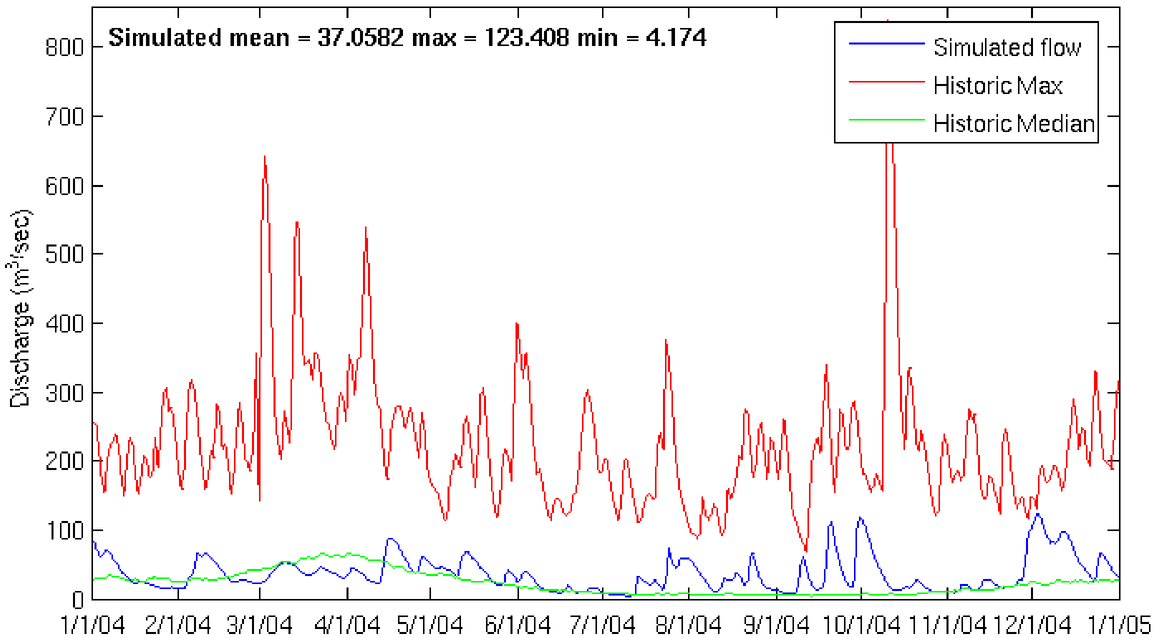


Figure 8. Passaic River Inflow at Dundee Dam, calendar year 2004.

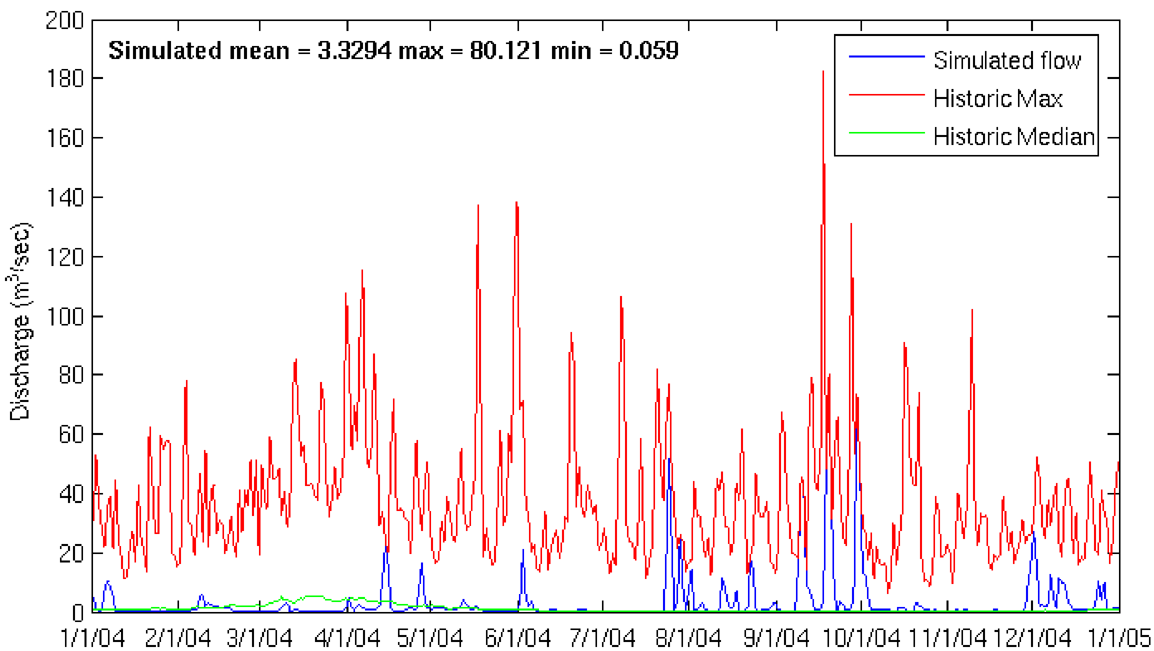


Figure 9. Hackensack River Inflow below Oradell Dam at Foschini Memorial Park for 2004.

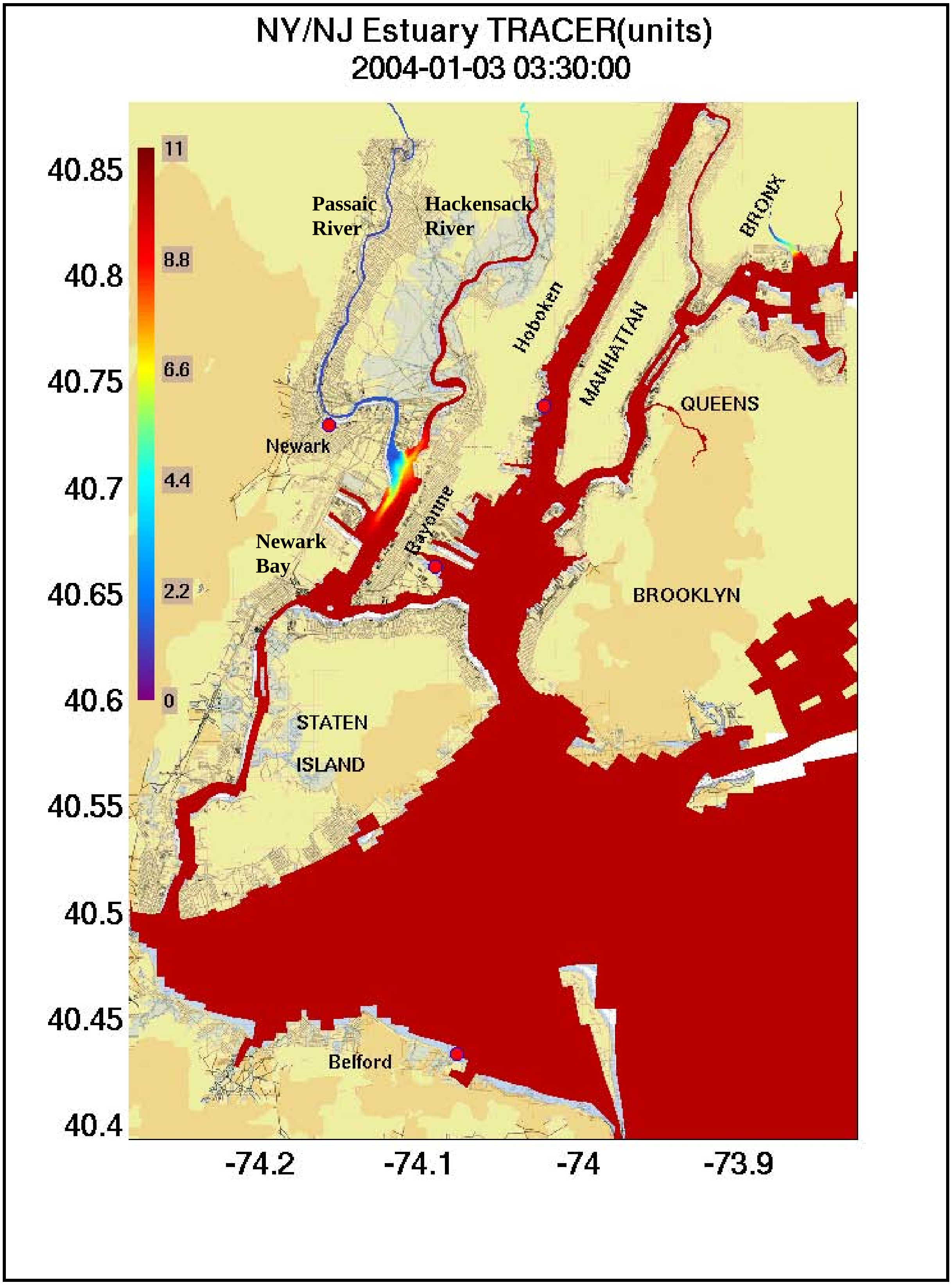


Figure 10. A tracer release from the river systems in the NY/NJ Harbor estuary. Ebb tide.

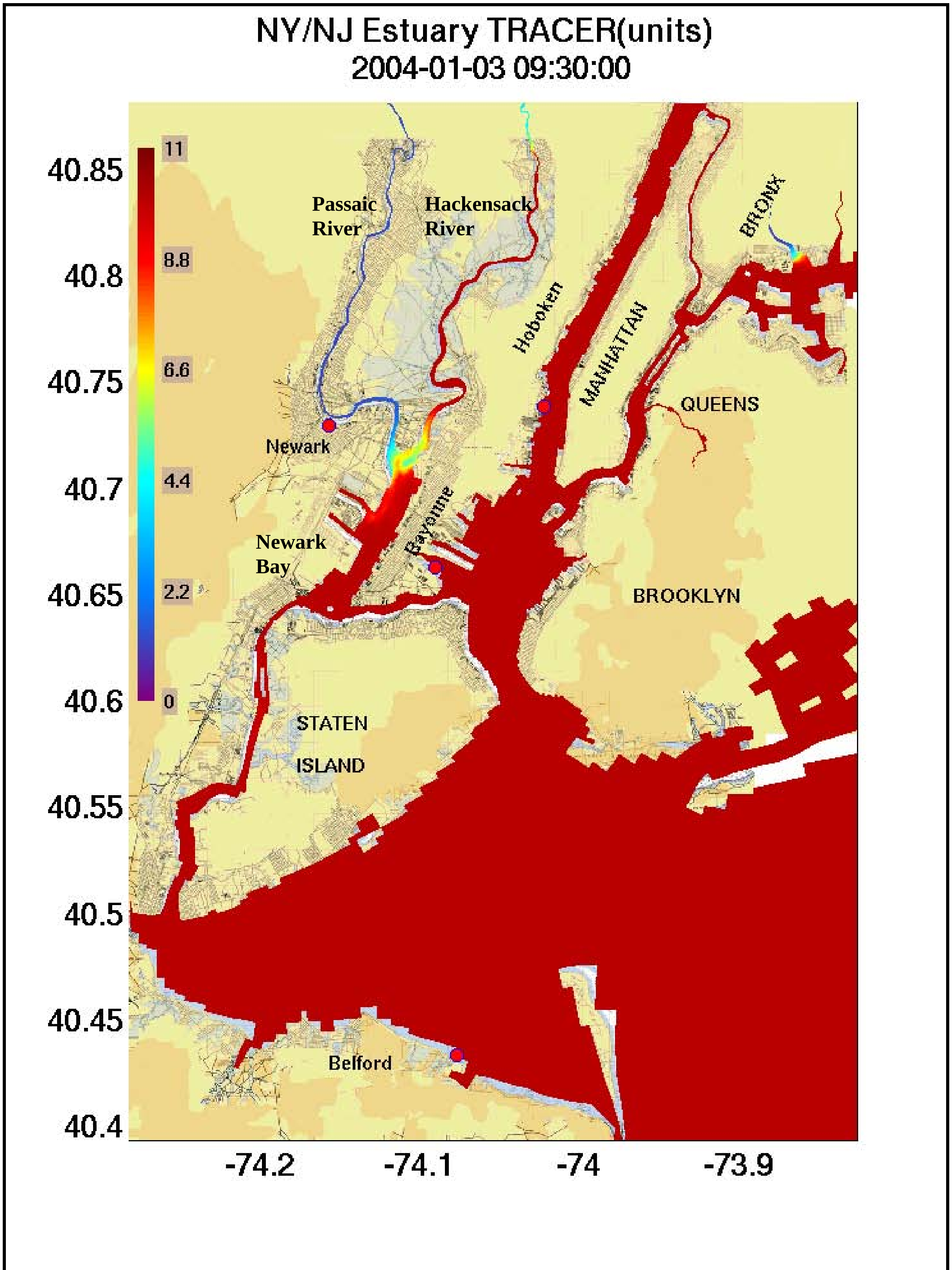


Figure 11. A tracer release from the river systems in the NY/NJ Harbor estuary. Flood tide.

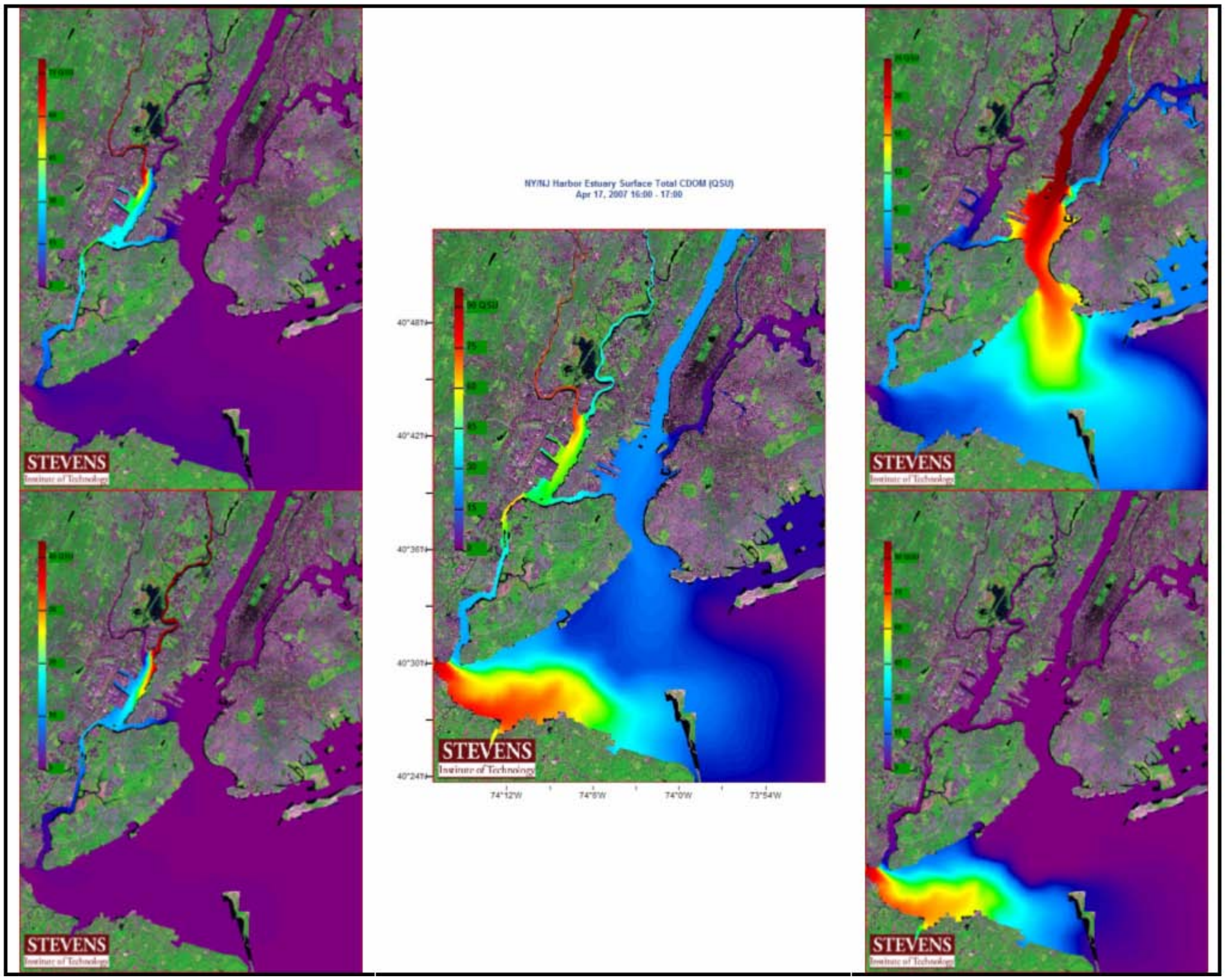


Figure 12. Screen captures of high resolution NYHOPS-predicted CDOM for April 17, 2007 16:30 ET. This date was one of major flooding all along northern New Jersey due to very intense and long-lasting rainfall. The various end members (clockwise from top left, Passaic River, Hudson River, Raritan River, and Hackensack River including the Bergen County water treatment plant), combine their strengths to create the central image which depicts the predicted CDOM concentration in the surface waters of the NY/NJ Harbor Estuary. Due to record-breaking river flows, maximum concentrations in the receiving waters equaled the end member strengths of Figure 4. Note the different scales in the end member color maps. The Hackensack river watershed inflow for this day was comparable to the inflow of the Passaic River, or two orders of magnitude higher than its historic median, making the CDOM contribution of the Bergen County plant comparatively insignificant (also see Figure 13). The contribution of the fifth end member, the Port Richmond WPCP outfall (not shown), is predicted by the model to be much less important due to an apparent 1:100 dilution factor in the vicinity of the outfall hypothesized to be due to the strong exchange of Raritan Bay, Newark Bay, and Upper Harbor waters happening through the Kills. Also visible are the mixing zone of the Hackensack and Passaic rivers (a line beginning at their confluence at Kearny Point and running along Newark Bay) and the mixing zone of the Hudson and Raritan rivers, running from Sandy Hook, NJ to Great Kills Harbor at Staten Island, NY, nicely delineating the boundaries of Raritan Bay and the Lower New York Harbor.

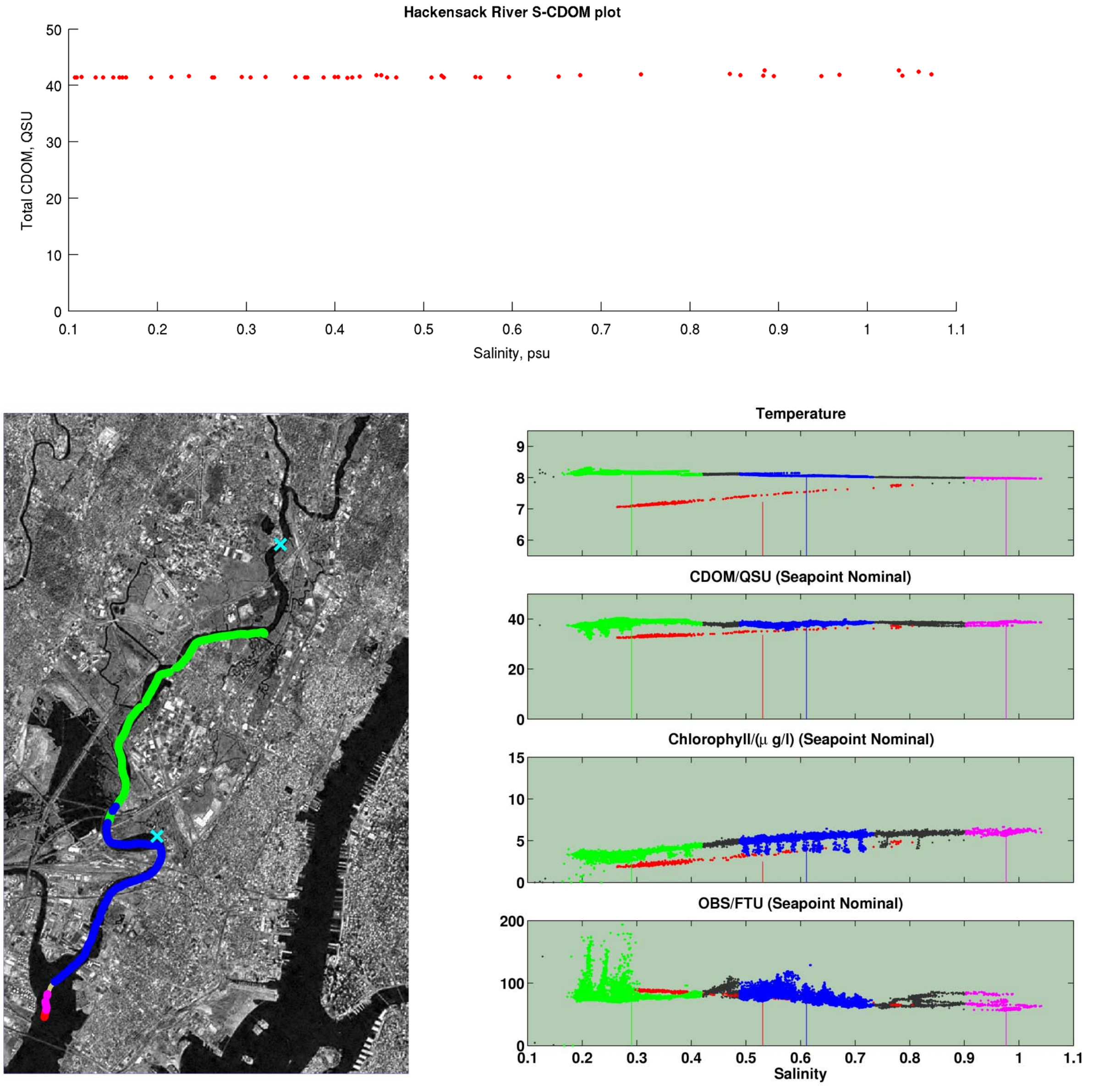


Figure 13. NYHOPS HIGHRES validation for April 17, 2007 major flooding event. Top panel shows high resolution NYHOPS CDOM model results predicted for the time observations (lower panels) were taken, between 16 and 18 hrs ET. Both model and data show that the Hackensack, influenced by historic inflows, was a freshwater river all along its span at the time that CDOM concentrations were measured. Both model and data show CDOM concentrations throughout the river close or equal 40 QSU, with an almost imperceptible slight increase at the Newark Bay outlet. Although due to tidal time logistics the observations stopped south of the Bergen County plant outfall, the CDOM load from the plant was diluted by the historic freshwater drainage inflows and cannot be discerned in the model.

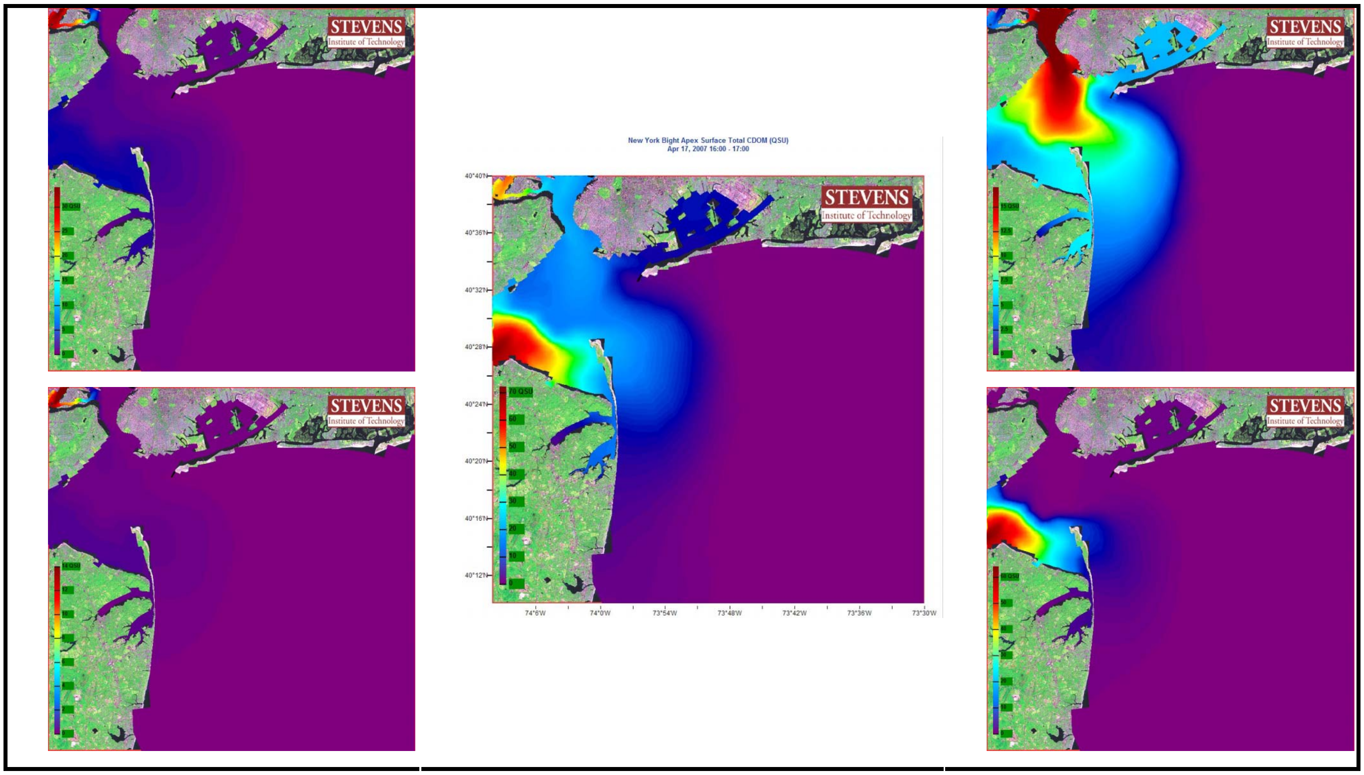


Figure 14. Screen captures of high resolution NYHOPS-predicted CDOM for April 17, 2007 16:30 ET, same time frame as in Figures 12 and 13. This date was one of major flooding all along northern New Jersey due to very intense and long-lasting rainfall. The various end members (clockwise from top left, Passaic River, Hudson River, Raritan River, and Hackensack River including the Bergen County water treatment plant), combine their strengths to create the central image which depicts the predicted CDOM concentration in the surface waters of the New York Bight Apex. Note the different scales in the end member color maps. Due to record-breaking river flows, considerable CDOM concentrations were predicted by the NYHOPS model to exit New York Harbor proper and influence the New York Bight region, hugging the northern New Jersey Atlantic shoreline carried by southbound alongshore transport.